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STATUS REPORT Nº 5

-:-:-

RESEARCH ON 8 MILLIMETER M-TYPE CARCINOTRON TUBES

July 1961

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A B S T R A C T

The tests on two circular and two linear tubes are reported. A discussion of the merits of the two types follows.

A number of technological improvements are described.

In the conclusion, one tries to define the parameters that limit the power and efficiency of the tubes. This leads to a program for the next quarterly period.

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DETAILED REPORT

I. TUBE TESTS.I.1. CIRCULAR TUBES.CM 07 CB N° 4.

This tube is described in section I.4 of status report N° 4. Figure 1 is a plot of the VSWR.

A further change was introduced. It was thought that the low efficiency of the previous tubes might be due to a loss of current directly from the sides of the cathode to the pole pieces. A pair of deflectors was added to the sole (similar deflectors were used in linear tubes and can be seen on photo 1). Due to the thermal expansion of the sole support in the axial direction, the deflectors caused a short circuit to the anode. This was found out after two unsuccessful tests. The deflectors were modified.

Figure 2 is a plot of output power and wavelength. This tube is limited at 35,700 Mcs and the output power is of the same order as in the previous circular tubes (about 7 W).

....



Figure 3 shows the influence of the heater voltage on line current, wavelength, output power and noise and demonstrates again that the cathode has to be temperature limited.

Figure 4 shows the wavelength as a function of time starting from the cold condition. The drift time is of the order 13 minutes.

Figure 5 shows output power versus beam voltage at nearly constant line voltage. The deflectors do not improve the results (see for instance figure 7 in status report N°4).

Similar results were obtained after sealing off the tube (Figure 6).

After a short time, it was found the filament was short circuited. When the tube was opened there were traces of oxidization. It could not be found at what time air was admitted.

The position of the sole was measured after opening the tube and was found to be about 0.02 mm off center. It may have been better before the tube was opened.

CM 07 C N° 3-5.

This tube is essentially the same as tube N°3. It was modified to accept the same sole centering device as tube N°4 and the sole deflectors.

Figures 7 and 8 show power and wavelength characteristics of the tube for two values of beam current. Figure 9 is a plot of output power versus beam current. These results are not substantially different from those obtained on tube N°3. It can be concluded from tubes 4 and 3-5 that the deflectors have no effect.

....

In these tubes, the anode block comprised between the accelerating plate and the ridge can be seen through the output window. This anode block became red hot in tube N°3-5.

In the measurements corresponding to figure 10, the temperature was kept constant by adjusting the beam current while the line voltage was varied. The upper curve shows the power delivered to the beam, the lower curve the beam current, the abscissa is line voltage. It can be seen that a lesser part of the beam power is lost on the anode block when the voltage of this electrode is higher.

Two explanations can be proposed. First, a dynamic space charge effect would be stronger at lower voltage. Then, it can be that the speed of the electrons at the point where they are collected decreases when voltage increases, if the scalloping of the trajectories decreases in the conditions.

This tube was sealed off. Data taken subsequently are shown on figure 11 and 12.

Power is 20 to 25 % lower for the same current ( $I = 125 \text{ nA}$ ). Perhaps the best sole centering was not found after scaling off.

CH 07 CD N° 6.

A relatively long time (6 weeks) elapsed between tubes 5 and 6, due to difficulties in machining the lines.

....

Tube N°6 has a line made out of zirconium copper and the fingers are 0.4 mm thick rather than 0.5. Figure 13 shows the VSWR measured without sole. It is smoother than ever, possibly due to the increased accuracy of the circuit, possibly to the higher impedance of the line.

Unfortunately, the line received a shock in its middle portion during assembly.

The tube was nevertheless assembled.

This tube was put on pump with a titanium getter and a sensitive ion gauge very close to its exhaust and can be sealed off with or without these.

Its pole pieces and titanium membrane are according to figure 23 of status report N°4. Parts of the sole support are shown on photo 2.

The cathode is of the new design shown on photo 3 and figure 24 of status report N°4.

Measurements are in progress. The sole centering is much easier than in the older design.

## I.2. LINEAR TUBES.

Drawings of the linear tube were given in status report N°3, figure 25. The sole was modified to accept deflectors (photo 1).

Photo 4 shows the circuit, with the ridge, anode block and collector cavity.

....

Photos 5 and 6 show two sides of the line base, showing the cooling jacket, wave guide and the circular base surrounded by the heliarc lips. Such a big base cannot be avoided as long as heliarc can be performed only on circular shapes.

Photo 1 shows the sole, its support, etc ....

Two tubes were assembled and tested. The parts are substantially longer to machine than for circular tubes, and the assembly is more difficult.

Both tubes had relatively poor circuits and were difficult to match to the waveguide.

CM 07 L 1.

Baking was very fast, the tube was apparently clearer than the other models. It was quite difficult to draw current from the cathode and the tube was opened. The cathode is the same as in circular tubes. The piece of alumina that supports the sole is a better thermic insulator in this tube than in the circular tube, but losses by radiation from the ceramic had probably been underrated. By cutting down the ceramic wherever possible, thus diminishing both kinds of losses, it was eventually possible to operate the tube with a heater power of some 20 watts, that the filament can stand at least for laboratory tests. The ceramic is seen on photo 1 after these modifications.

Figure 14 shows the VSWR of the tube. It is very poor, but it is usually worth while to assemble a first model even in these conditions.

....

After an hour of operation with high voltage, a short circuit developed from sole to ground. Eventually, it was suppressed by passing a strong current through it.

No measurable rf power was obtained and practically as much radiated through the stem as through the wave guide. It was not even possible to measure the wavelength.

Photo 7 is an oscilloscopic display of rf power versus line voltage. It is indicative of strong circuit reflexions.

After outgassing the titanium pump, the tube was sealed off with to pump and gauge, and the VSWR was measured again (figure 14). It was worse than before. The tube was opened. Photo 7 shows the circuit.

After three baking operations, the stainless steel cover had collapsed and pressed the two interdigital combs together. Such a cover had been tested before in a blank test in order to measure the deformation due to baking. However, after a number of bakings, the effects add up.

CM 07 L 2.

Figure 15 shows the VSWR of CM 07 L 2 before and after operation.

Figure 16 shows the output power and wavelength of the tube. The tuning range is similar to that of the CM 07 C, the power is low.

....

Figure 17 shows the output power versus line current, figure 18, versus heater current for constant line current.

It was thought that the matching of the guide to the line had deteriorated. The tube was sealed off with pump and gauge. The vacuum became much better after this operation (about  $10^{-7}$  mmHg).

No more measurable power could be drawn. This is not due to sealing off, but to arcs that occurred shortly before or after it. Figure 19 shows the wavelength/voltage curve for slightly different magnetic fields at the beginning and at the end of the life of the tube.

The tube was opened. The first finger had melted.

### I.3. CONCLUSION CONCERNING LINEAR TUBES.

It has been said earlier that linear tubes take more hours of machining and are considered more difficult to assemble. It is apparent that their technology as of now is unsatisfactory. The performance of tube N°2 was lower than that of the 5 circular tubes that have operated all alike or nearly. No new linear tubes will be made. The existing parts will be assembled again if this does not delay the circular models.

## II. TECHNOLOGY

### II.1. CIRCUIT MACHINING.

Zirconium copper appears easier to machine than standard OFHC copper. No results are yet available on tubes using these circuits (CM 07 N26).

After a period of difficulties with circuit machining, efforts were undertaken to obtain better saw mills and to sharpen them better. This resulted in a series of circuits that have a much better aspect under the microscope. There is practically no bending of the fingers. The coming series of circular tubes will be equipped with these circuits.

The Tube Department of C.S.F. has been asked to try and make a hob for these tubes. Grinders of the desired thickness (0,08 mm) are not commercially available. The first operation is to thin down a commercial grinder. The first results are encouraging.

### II.2. HOBGING OF THE CROWN.

The different hobs shown on photo 2 of status report N23 have all broken. In these tests, the first hobbing, forming the crown, hardens the metal. It is then no more possible to perform the second, perpendicular hobbing. This method has been abandoned, and a less ambitious program is being followed, where the prismatic guide with the ridge, or a slot to lodge it, would be made by hobbing. The rest of the crown would be lathed later. This would simplify the

....

present method of assembly of the lines, shown on figure 6 of status report N<sup>o</sup>3. The first test has not been successful because the temper of the hob was too soft.

### II.3. CERAMIC WINDOWS.

A number of ceramic windows have been brazed directly to copper wave guide (photo 9) and vacuum tested (photo 10). The results are still not reliable. A titanium-ceramic braze has been designed (figure 20). The parts have been made, but not yet tested..

### II.4. NEW CATHODE SUPPORT.

The new cathode support (photo 3 and figure 24 of status report N<sup>o</sup>4) has been tested.

This cathode will be used in all tubes starting with CM 07 C N<sup>o</sup>6. For a temperature of 1000°C, the heater power has decreased from 13 to 10 watts.

-:-:-



### III. PERMANENT MAGNETS

Since tube N<sup>o</sup>3-5 had been sealed off and worked with low magnetic field (5600 Gauss), one tried to provide it with pole pieces AM 552 described in an early status report. Intermediate parts had to be designed (photo 11, right). The field was only 3500 Gauss.

The new magnet elements shown on figure 30 of status report N<sup>o</sup>3 have been obtained. Each element weighs 740 gr. (photo 11, center). With the pole pieces with round edge of the earliest design, and four elements, a field of 6700 Gauss could be obtained with a gap of 8 mm. These figures are satisfactory, but they do not correspond to the new pole pieces.

With the new pole pieces, the results were at first disappointing. The magnetic leakage is quite strong. Furthermore, the ends of the magnetic elements are too small. 400 Gauss were gained by grinding 8 mm away at each end of the elements.

Some further modifications of the pole pieces (figure 21) improved the field without changing its variation in the region of interest (photo 11, left). The following results were obtained :

....

with 4 elements ..... 5480 Gauss  
with 5 elements ..... 6800 Gauss  
with 6 elements ..... 7500 gauss

The field plotted after demagnetization (1000 gauss instead of 7500) was the same as before. So, the pole pieces were probably not saturated.

6800 Gauss was the standard field of the CM 08 and 5600 was used on several CM 07's. On this basis, the packaged tube would weigh 13 lb with 5 elements or less than 15 lb with 6 elements. These figures will probably be improved in the coming weeks.

--:--

#### IV. CONCLUSION AND PROGRAM

Improvements have been obtained concerning circuit machining, vacuum, hobbing of interdigital lines, sole centering device, cathode and magnets.

The linear tubes will not be continued actively.

The results on circular tubes N°4 and 5 just confirmed the results obtained on tubes 1, 2 and 3. So far, the main advances over the CM 08 are in the range of frequencies and the reproducibility of the results. Much is expected from the improved circuits, but the better CM 08's delivered more than 15 or 20 watts and their circuits were mediocre. Electrically, the main differences between the two types are :

- Circuit dimensions.
- Operating magnetic field (determined by trial).
- Presence of the wide anode block in the CM 07.
- Barrel-shaped magnetic field in the CM 07.

....

The first factor will be changed in the future because the present tuning range extends too far to the high frequencies. The second factor is not freely chosen. The anode block was not present in CM 07 Nos. 1 and 2, and there is no big difference with tubes 3 through 5 concerning efficiency and output power. So far, the obvious effect of this anode block is to protect the first fingers from direct electron bombardment that wrecked most good CM 08's.

The last factor - magnetic field map - will be investigated as soon as possible. Drawings for a tube with flat pole pieces have been made. Meanwhile, the technological improvements mentioned earlier will be incorporated to the tube.

--:--:-

FIGURES

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- Fig.12. {
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- Fig.14. VSWR of CM 07 L 1.
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- Fig.16. Output power and wavelength (CM 07 L 2).

....

Fig.17. Output power versus line current (CM 07 L 2).

Fig.18. Output power versus heater voltage (CM 07 L 2).

Fig.19. Frequency characteristics of CM 07 L 2.

Fig.20. Drawings of titanium-ceramic window.

Fig.21. New profile of pole pieces.

-:-:-

А. В. С. И. Р.

CM076 №4

Fig. 1

10

5

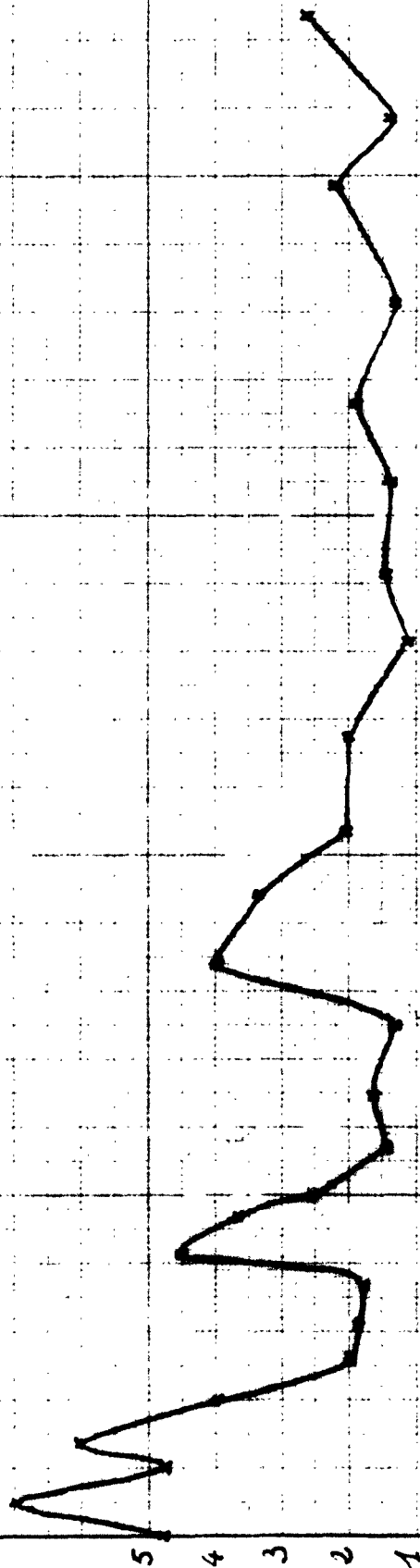
4

3

2

1

$\lambda_{cm}$





# CM07C N°4

$I_{c, max} = 185 \text{ to } 165 \text{ mA}$

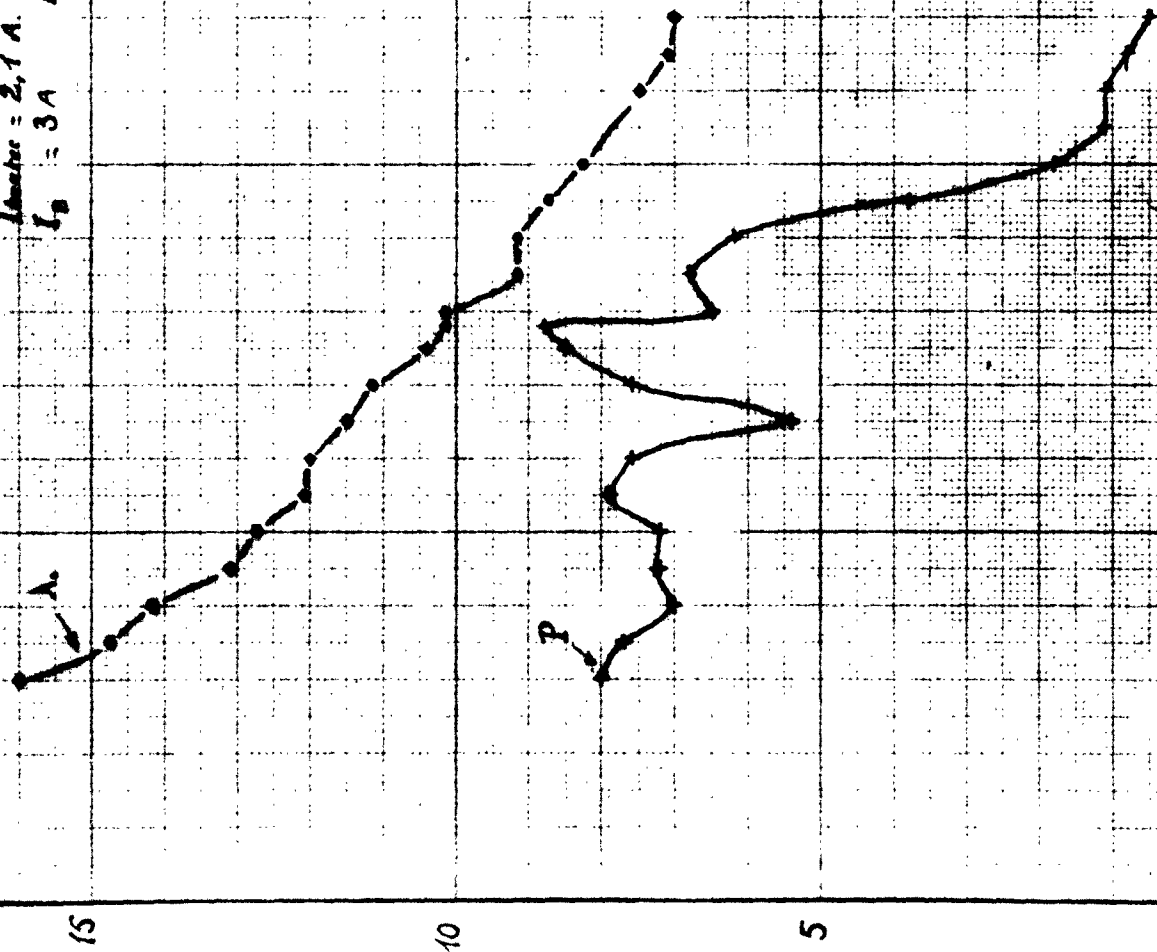
$V_p = 1800 \text{ to } 1250 \text{ volts}$

$V_{break} = 5,75 \text{ volts}$

$I_{break} = 2,1 \text{ A}$

$I_B = 3 \text{ A} \quad B = 6.770$

Fig.2

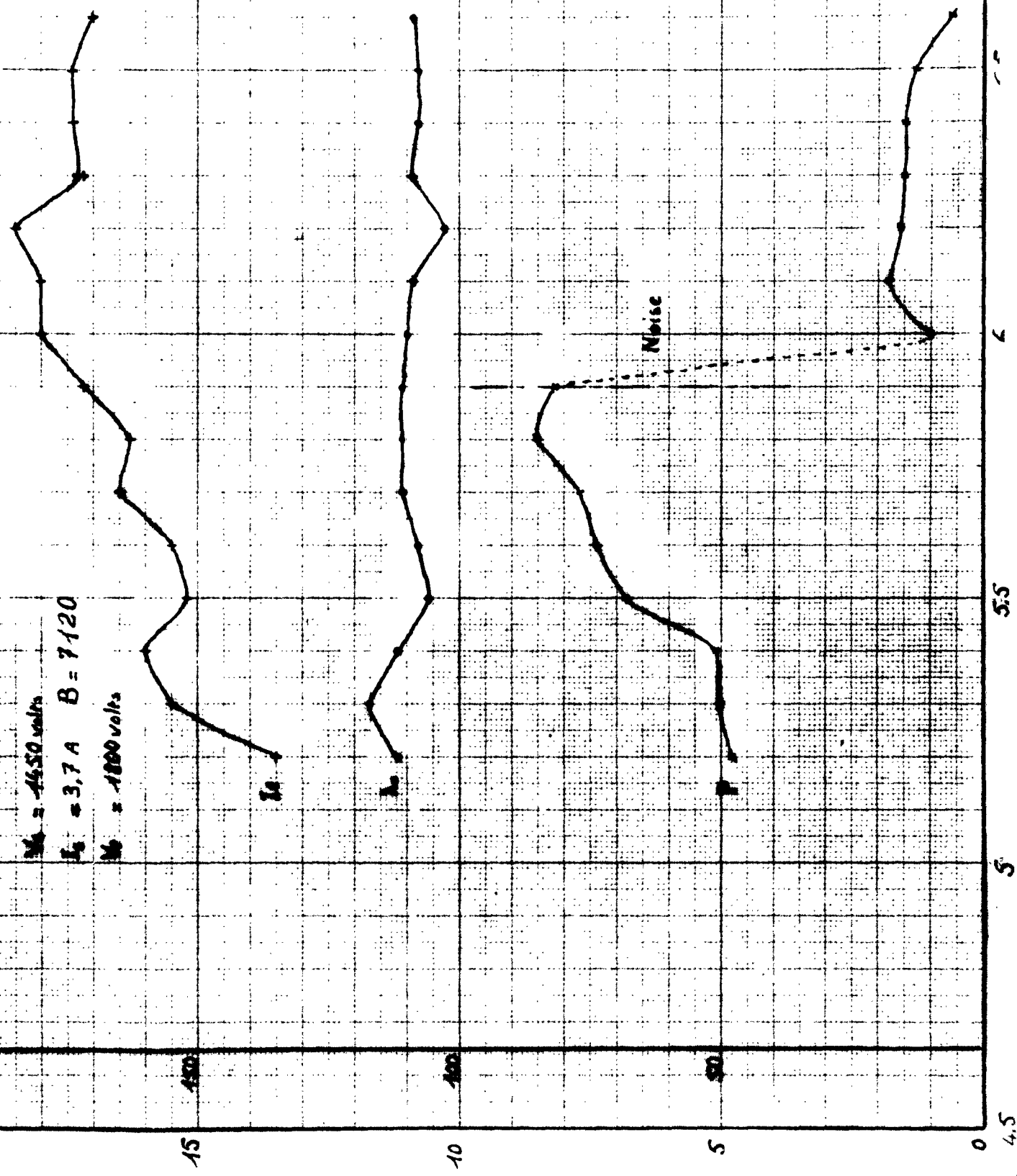


Power, I<sub>line</sub>  
mW

CM07C №4

Fig. 3

$M_A = 4650 \text{ volts}$   
 $I_A = 3.7 \text{ A}$   $B = 7120$   
 $M_B = 1800 \text{ volts}$



CM07C N° 4

Fig 4

$V_g = 1400$  volts

$V_s = 1450$  volts

$V_{heater} = 64$  volts

$I_{heater} = 3,18A$

$B = 6.770$

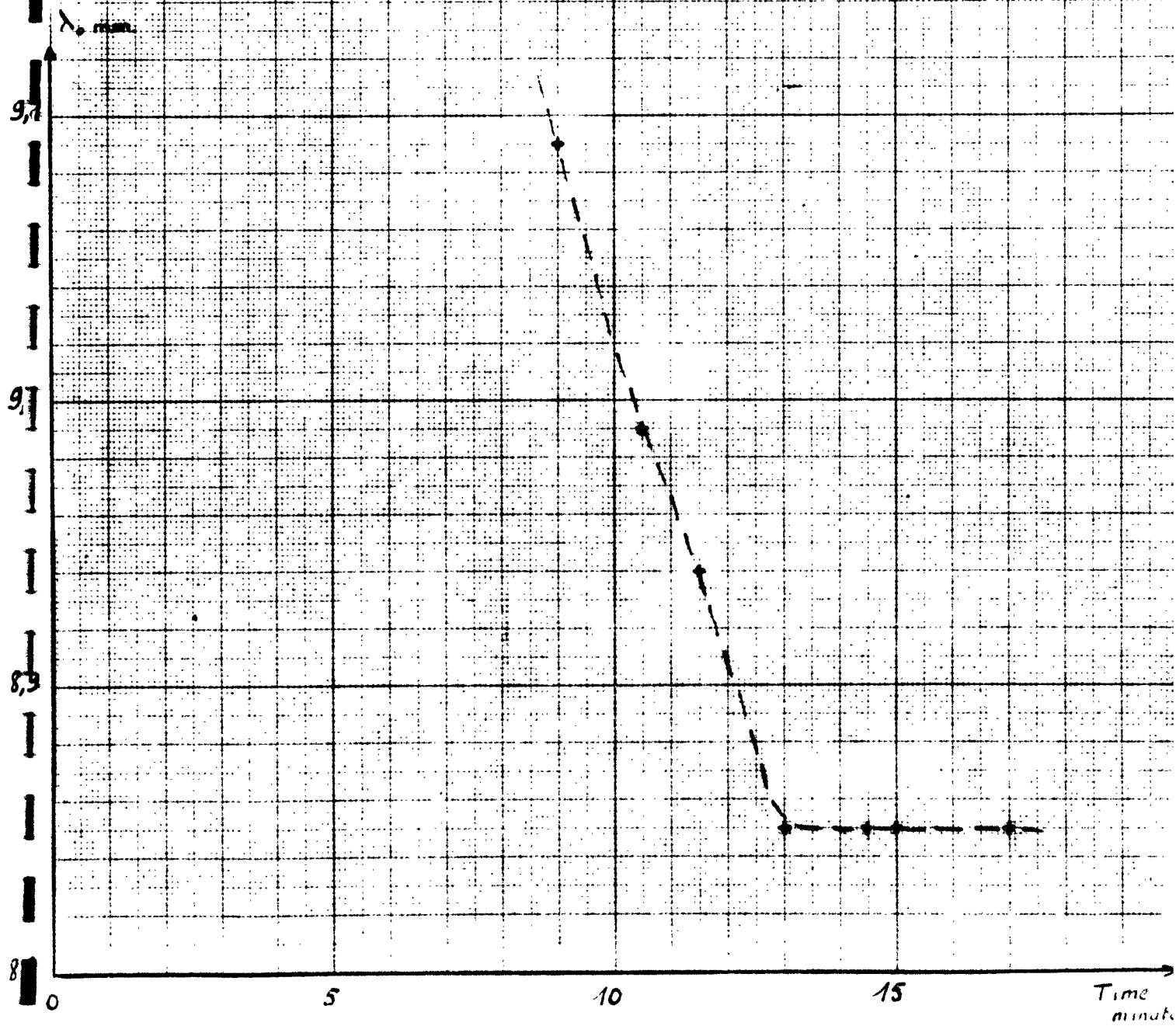


Fig. 5

GM107C No. 4

$V_p = 1750$  volts

$V_s = 1380$  volts

$\lambda_d = 9.07$  mm

$B = 6.770$

$V_{heater} = 5.75$  volts

$I_{heater} = 2.40$  A.

P volts

10

5

0

10 mm

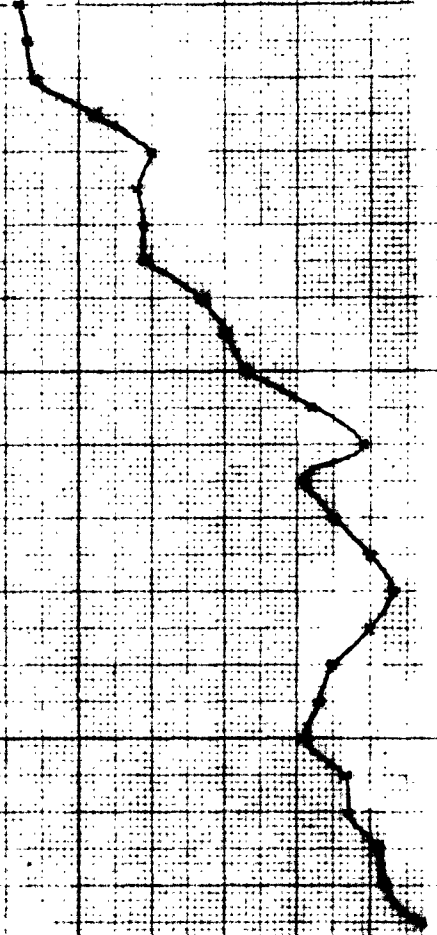


Fig. 6

CM07C №4

Ручка  
Автом

15

10

5

0

50

100

150

200

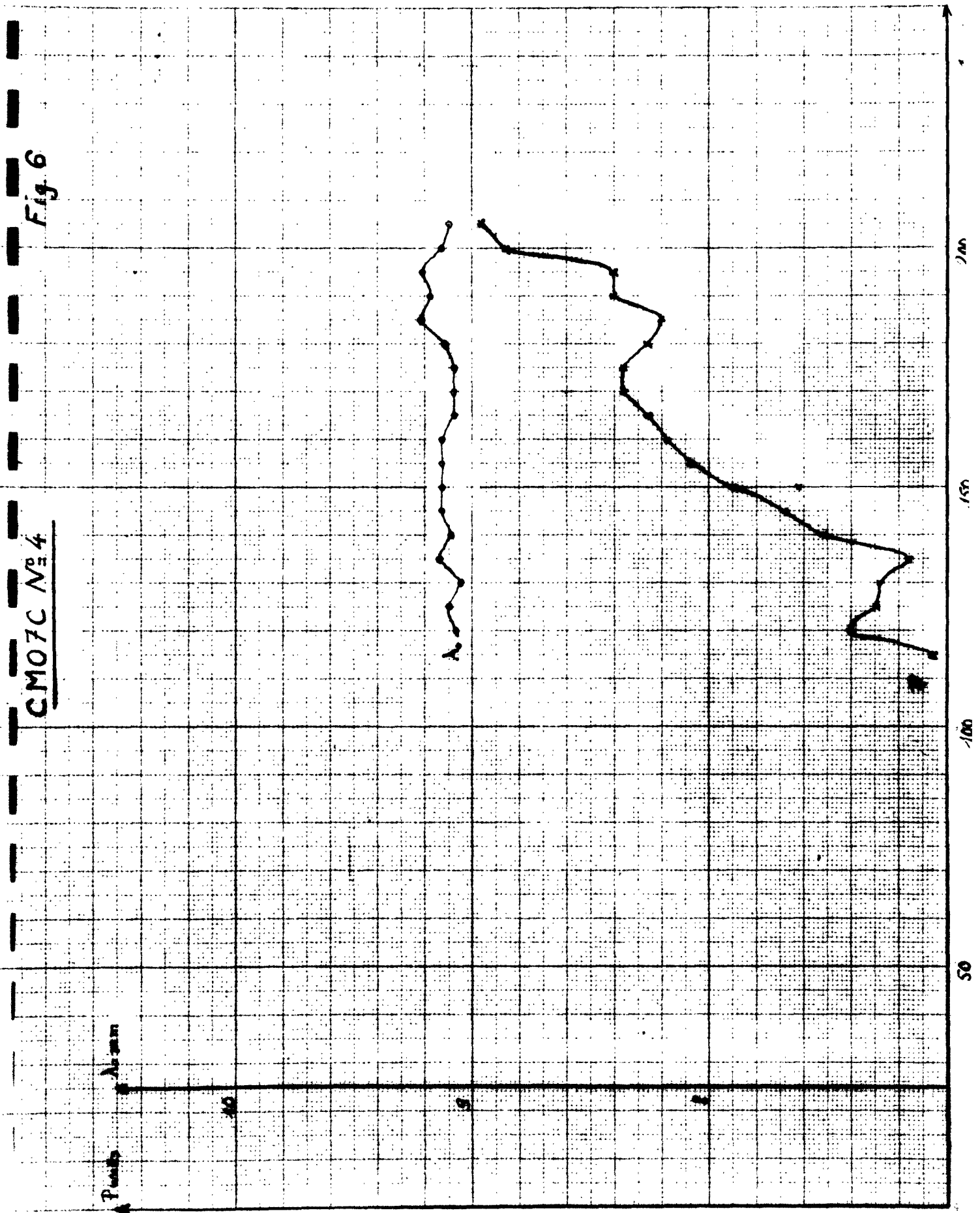


Fig. 7

CM07C N° 3-S

$V_G = 14.25$  volts

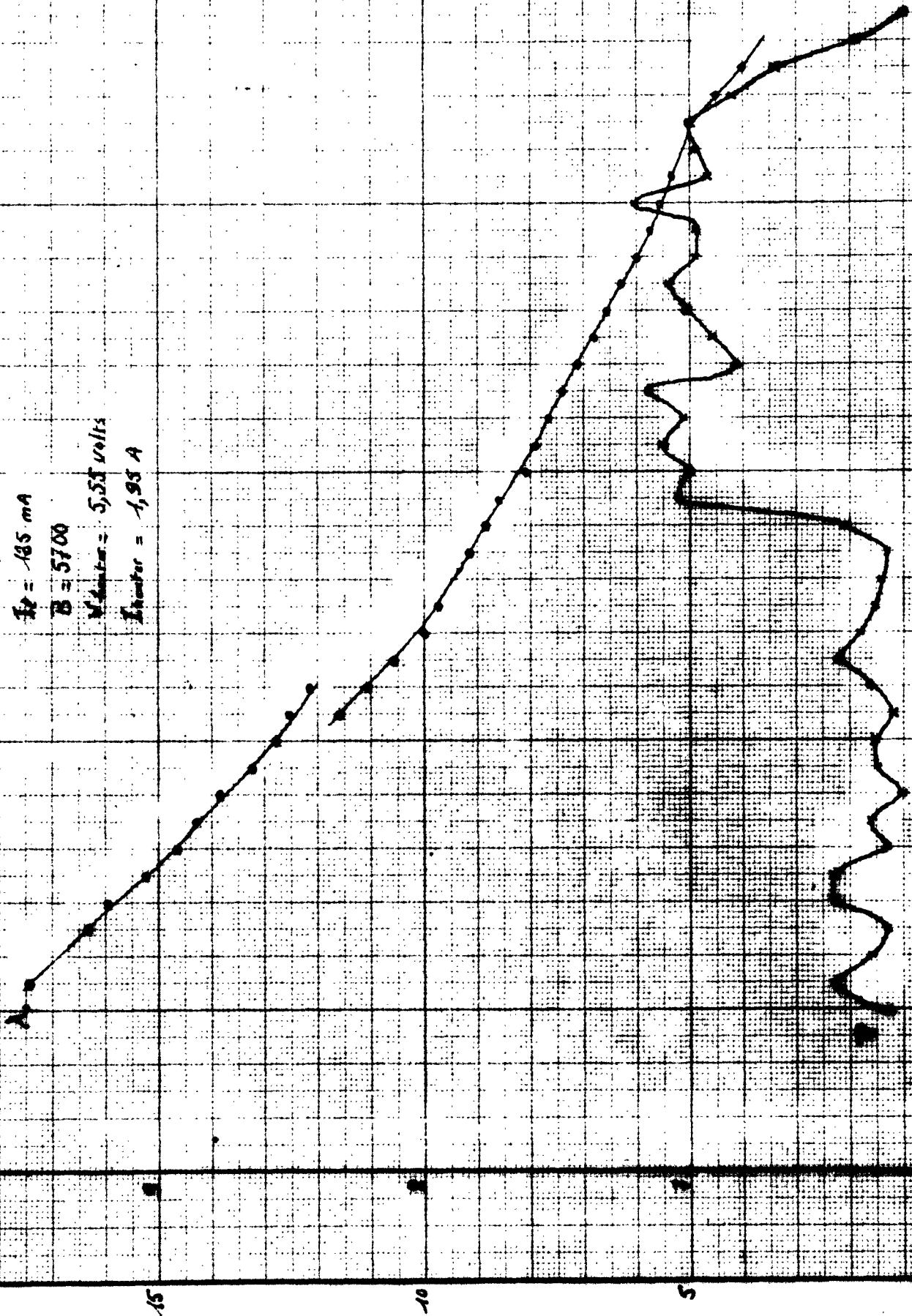
$I_F = 185$  mA

$R = 5700$

$V_{\text{anode}} = 5.53$  volts

$I_{\text{anode}} = 1.93$  A

Power  $\lambda_{\text{max}}$



GM07C N23.5

Fig. 8

$V_s = 1430$  volts

$B = 5700$

$I_q = 150$  mA

$V_{\text{heater}} = 5.6$  volts

$I_{\text{heater}} = 1.95$  A

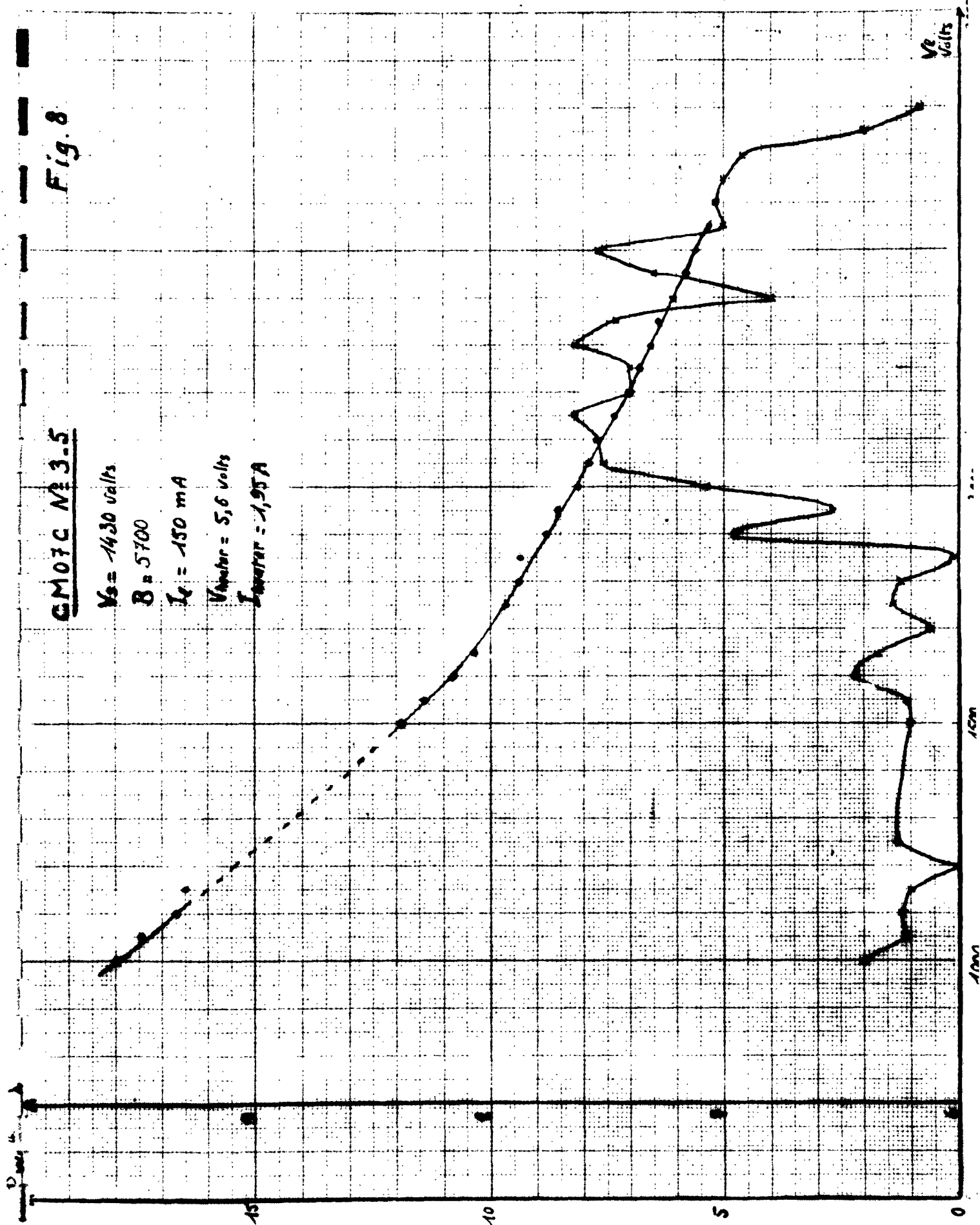


Fig. 9

CM07C №3-5

$V_e = 2150$  volts

$A_e = 7,48$  mm

$V_s = 1430$  volts

$B = 5700$

$V_{anode} = 5,6$  volts

$I_{heater} = 1,95$  A

$I_{watts}$

$k$

150

100

50

0

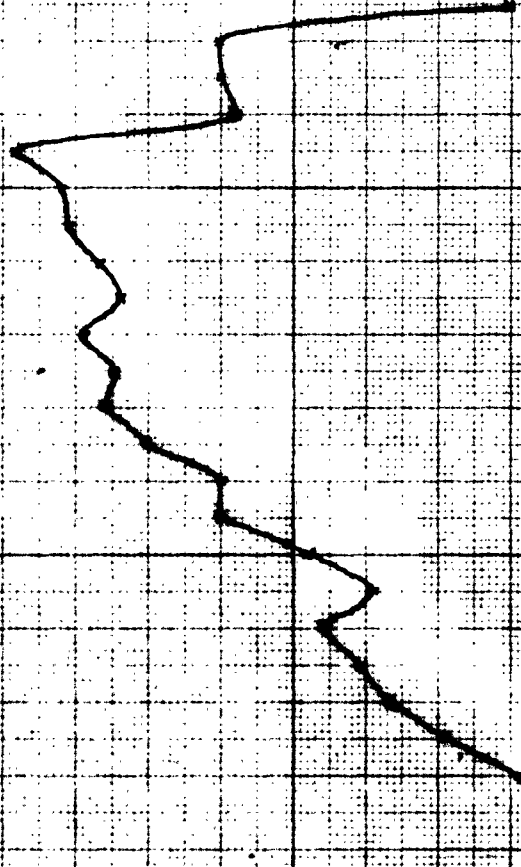




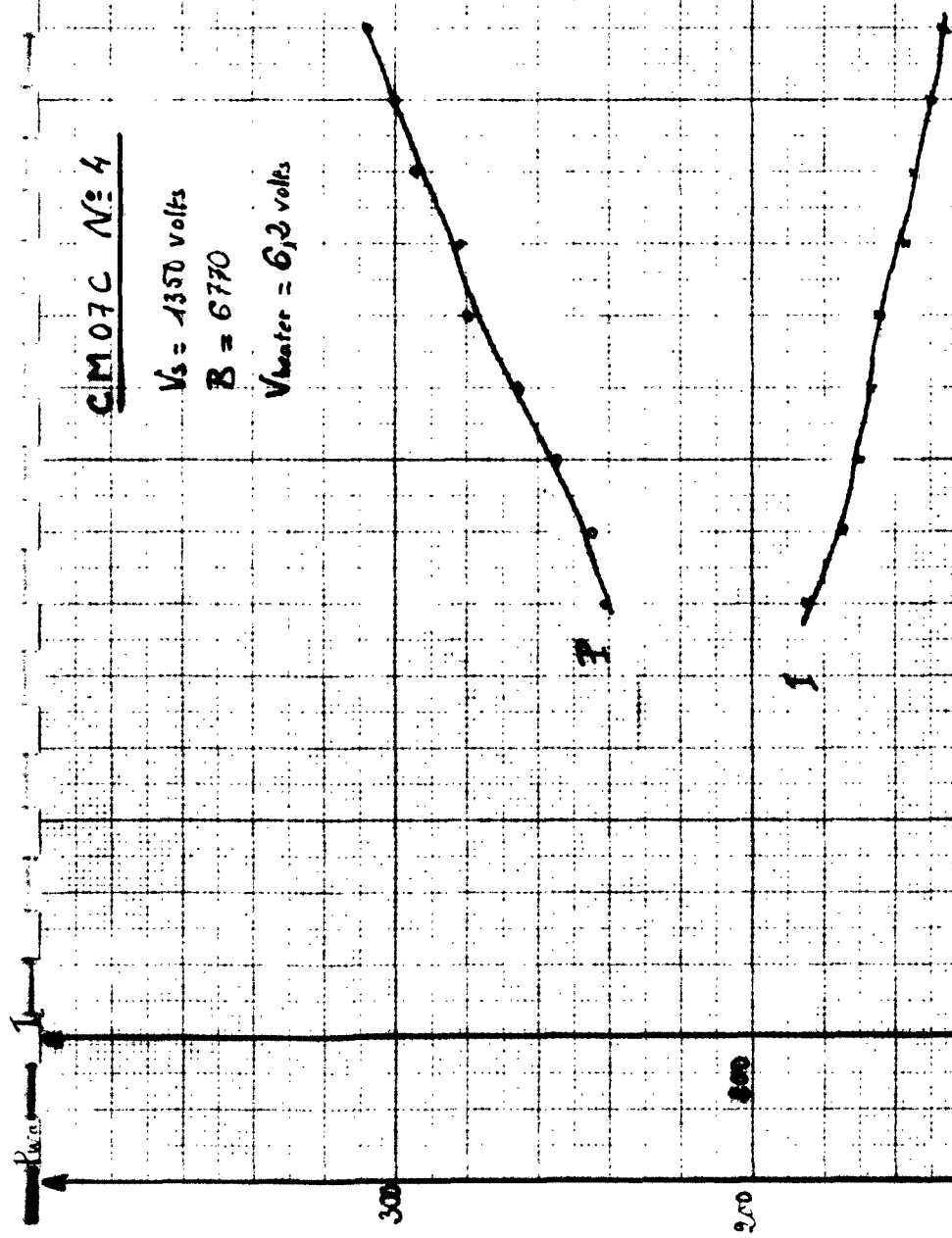
Fig 10

CM07C N:4

$V_s = 1350$  volts

$B = 6770$

$V_{heater} = 6.3$  volts



CM07C No 3.5

$I_0 = 100 \text{ mA}$

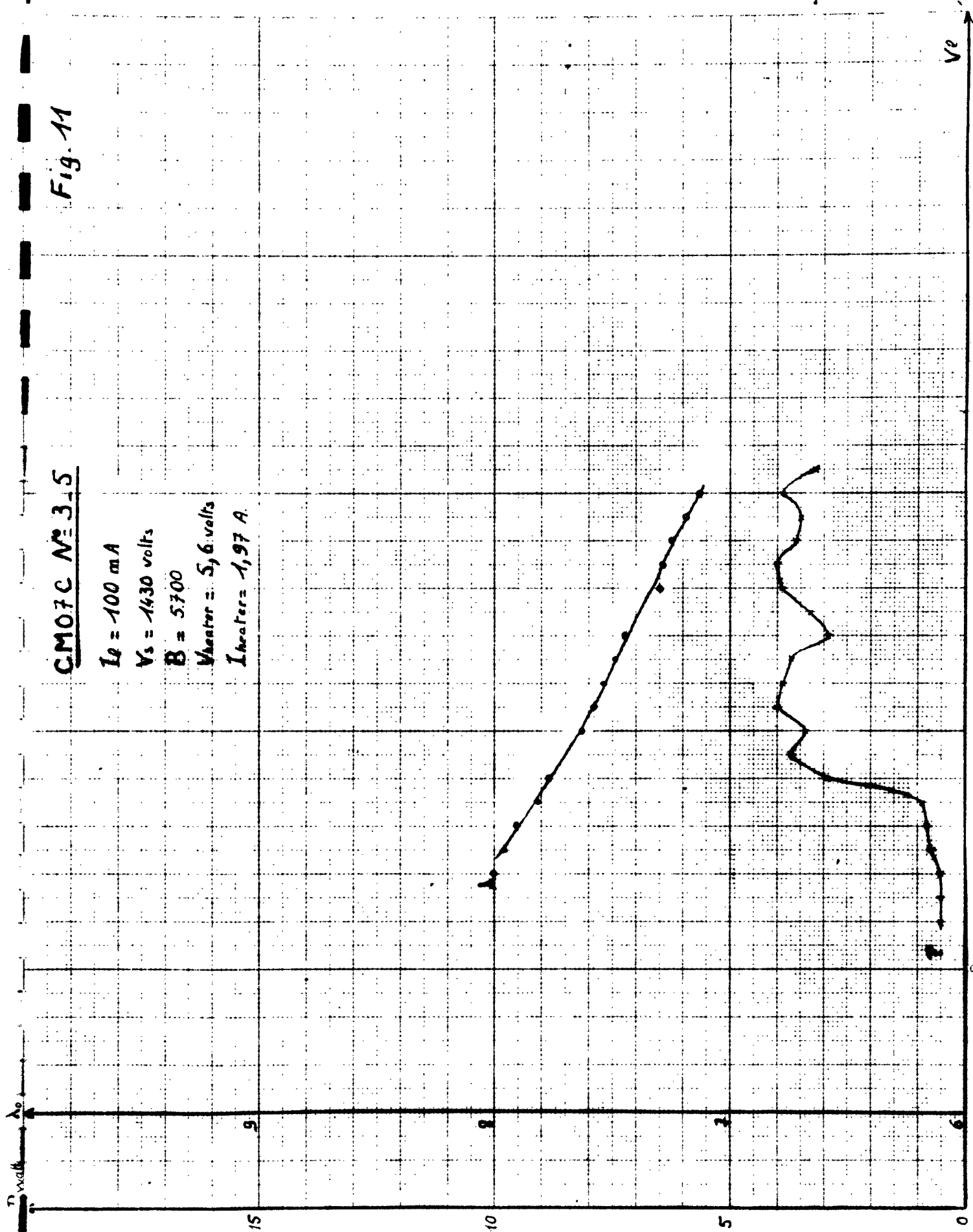
$V_s = 1430 \text{ volts}$

$B = 5700$

$V_{\text{heater}} = 5.6 \text{ volts}$

$I_{\text{heater}} = 1.97 \text{ A}$

Fig. 11



Pulsals  $\Delta$  mm.

CM07C № 3-5

Fig 12

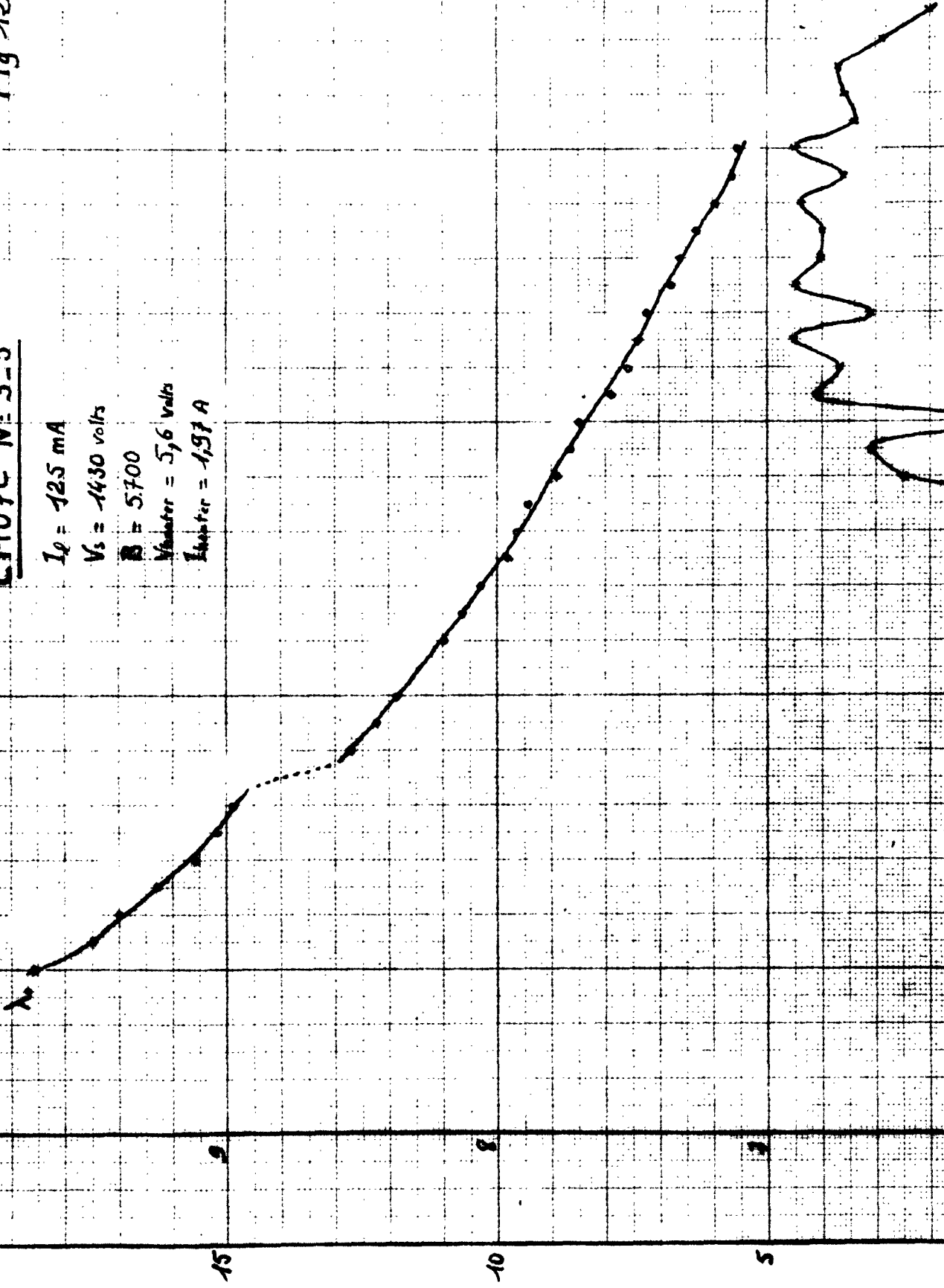
$I_0 = 125 \text{ mA}$

$V_s = 1430 \text{ volts}$

$B = 5700$

$V_{\text{meter}} = 5,6 \text{ Volts}$

$I_{\text{meter}} = 1,97 \text{ A}$



CM07CD № 6

Fig. 13

NSWR

$\lambda$   
mm

7.5

8

8.5

9

$\lambda$   
mm

7

1

2

3

4

5

6

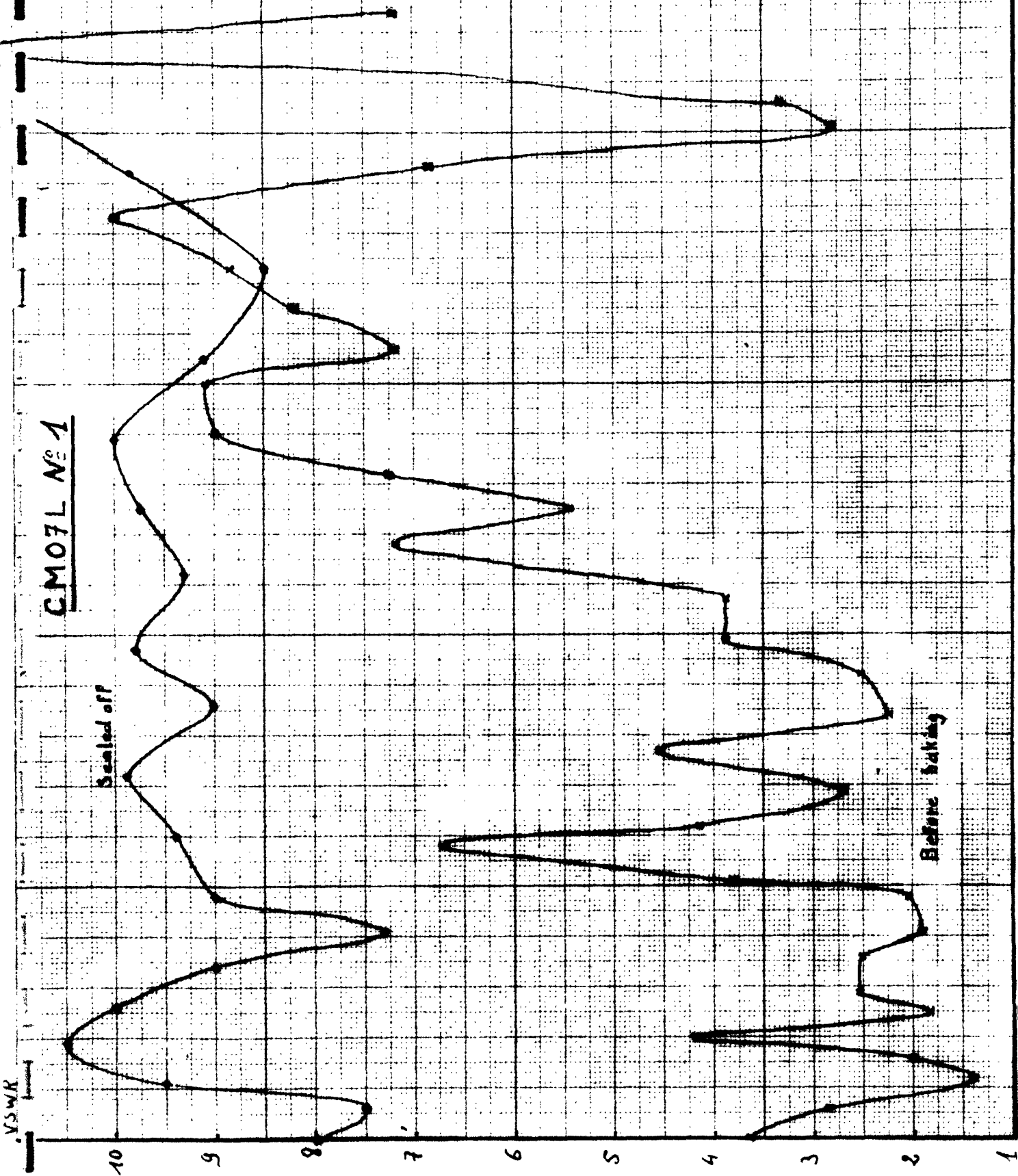
VSWR

CM07L No 1

Fig. 14

Sealed off

Before baking



NSW/K

CM07L N:2

Fig. 15

Sealed off

Before baking

mm

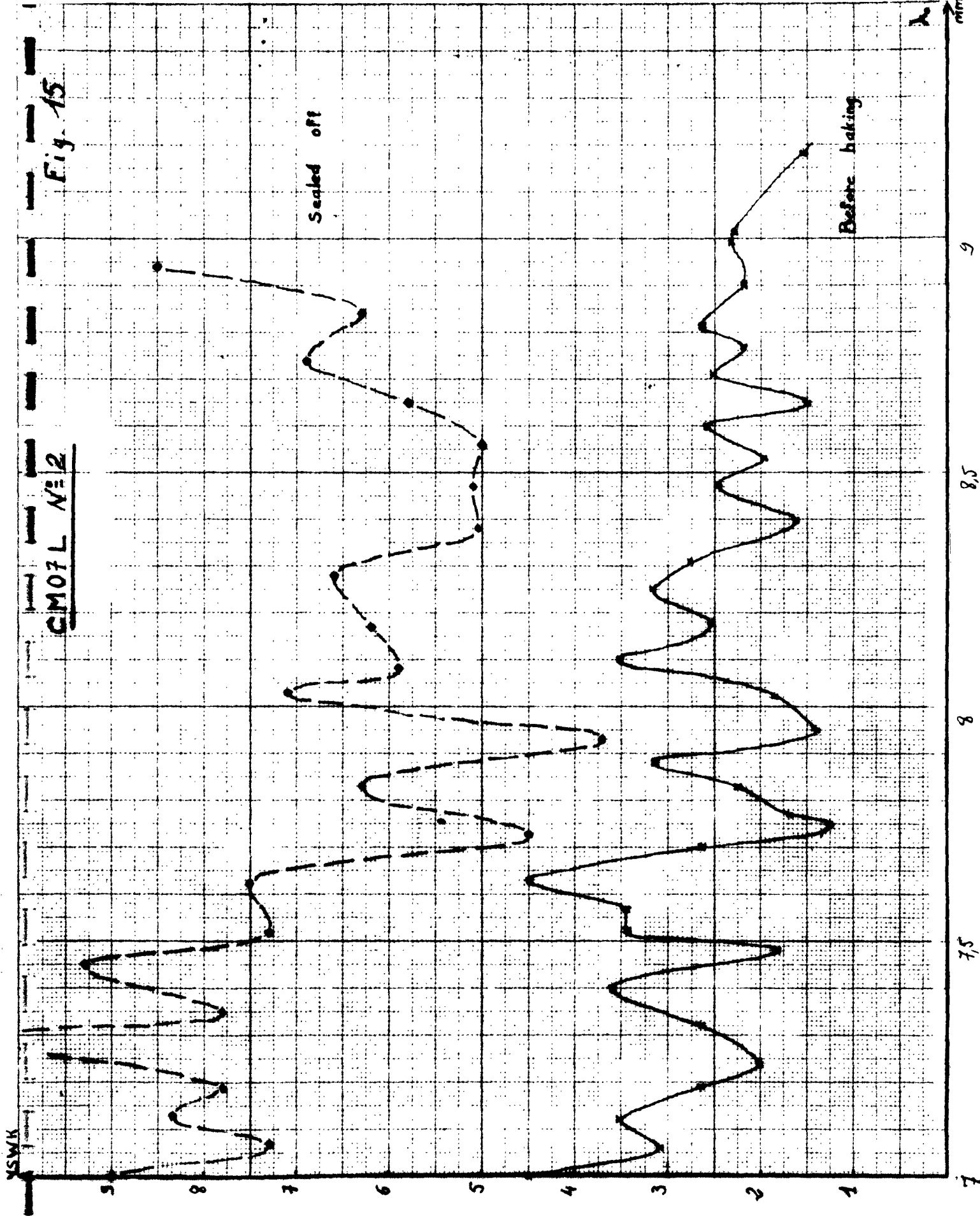
7

7.5

8

8.5

9



CM07L N°2

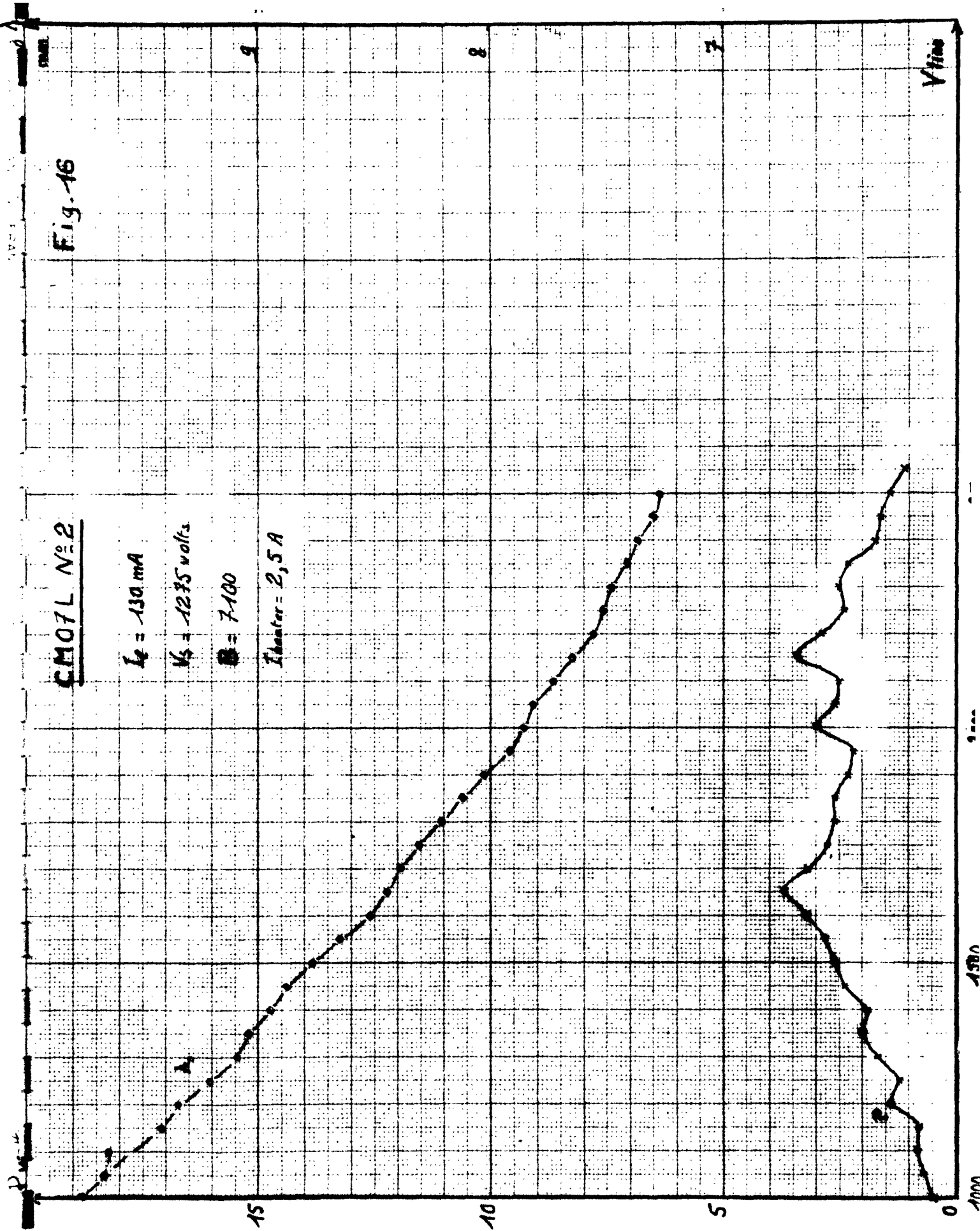
$I_e = 130 \text{ mA}$

$V_s = 1275 \text{ volts}$

$R = 7100$

$I_{heater} = 2,5 \text{ A}$

Fig. 16



P watts

CM07L N°2

Fig 17

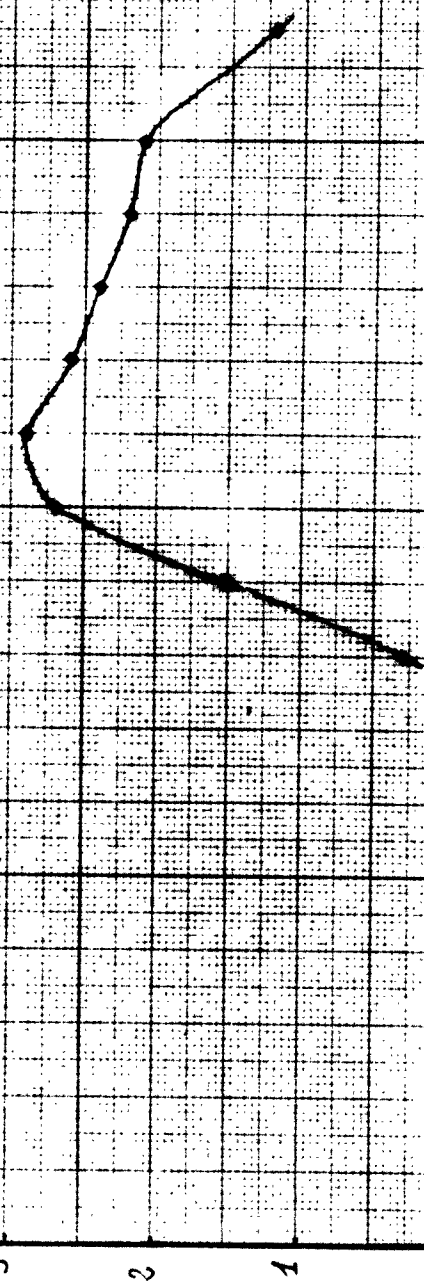
$V_b = 1275$  volts

$B = 7100$

$\lambda_c = 8,65$  mm.

$V_{heater} = 6,5$  volts

$I_{heater} = 2,45$  A.





CM07L N: 2

Fig. 18

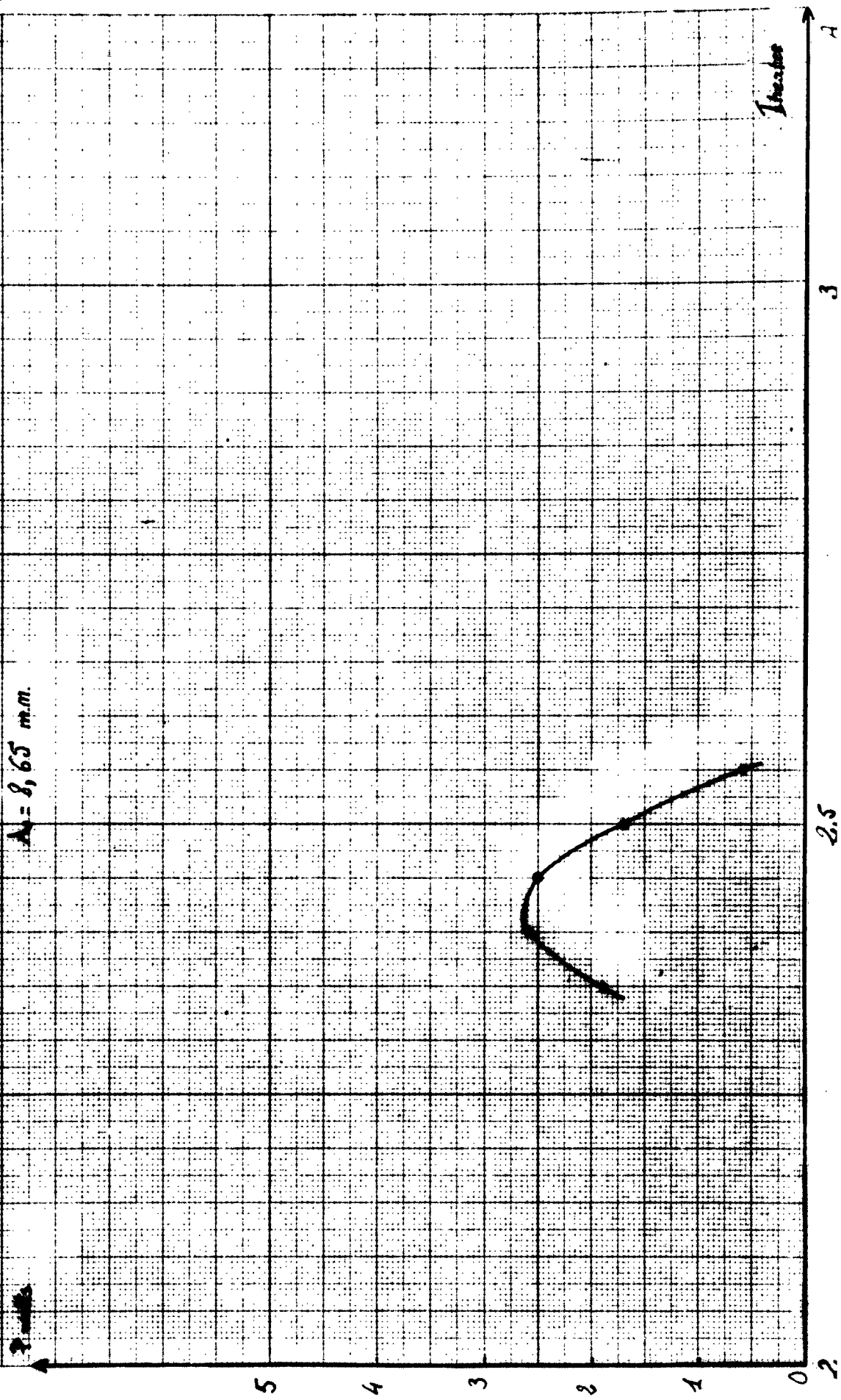
$I_d = 100 \text{ mA}$

$V_d = 1275 \text{ volts}$

$R_L = 7.100$

$A_d = 8,65 \text{ mm.}$

$P_{\text{max}}$

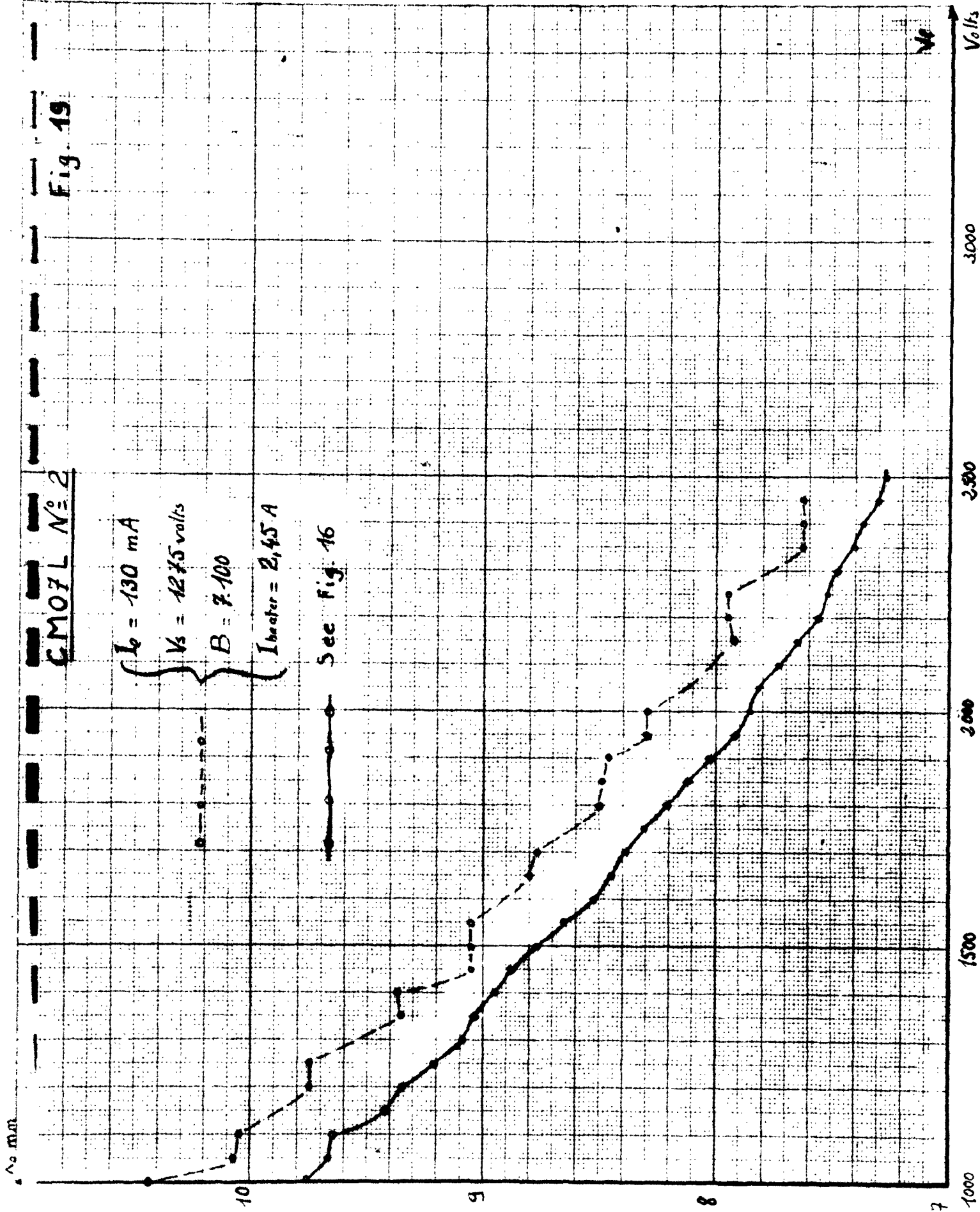


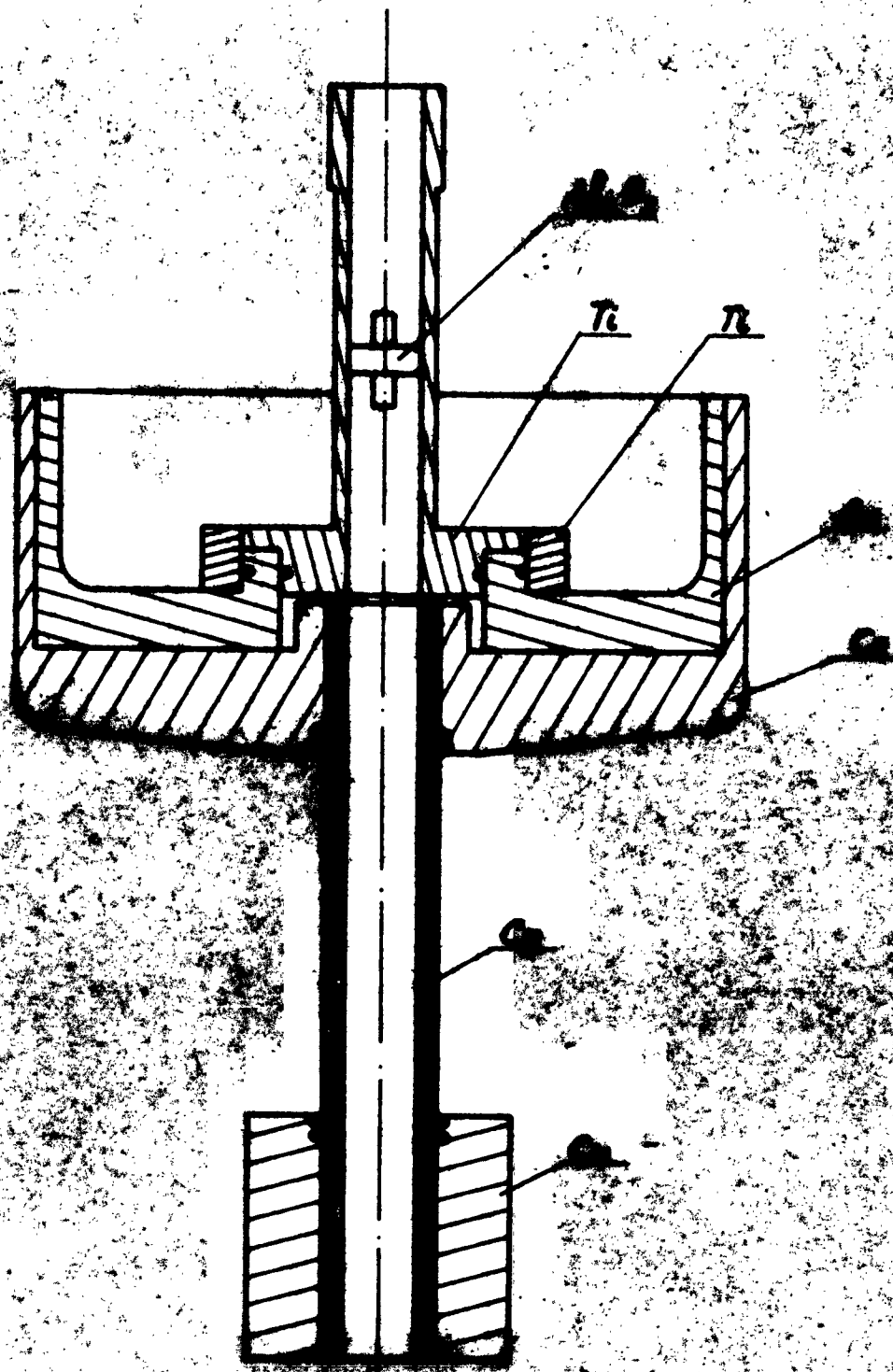
CMO7L N° 2

Fig. 19

$I_p = 130 \text{ mA}$   
 $V_s = 12.75 \text{ volts}$   
 $B = 7.100$   
 $I_{heater} = 2.45 \text{ A}$

See Fig. 16

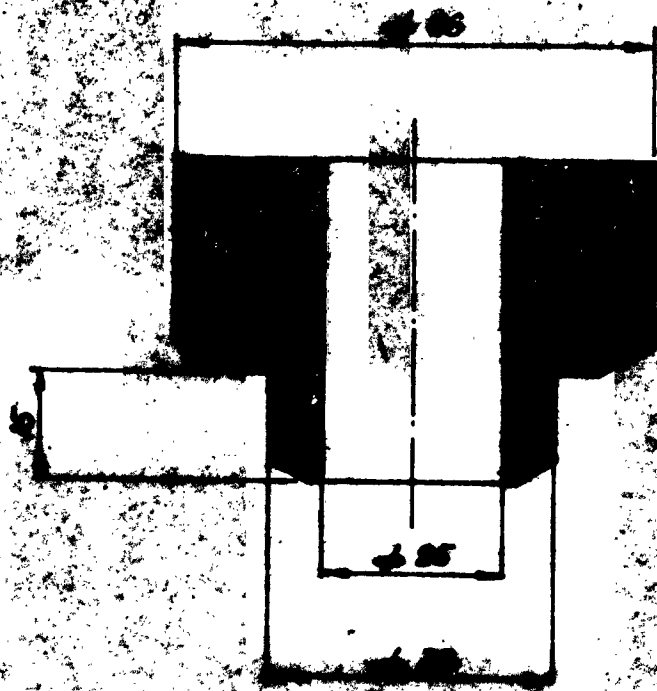




CSF

Titanium-Aluminum window

Fig. 20



Ech. 1/4

*Handwritten initials or signature*

*New profile of pole pieces*

*Fig. 21*


LIST OF PHOTOS

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- Element of new magnet.
- Magnetic circuit with 6 elements (right to left).

